63-3-4

UNCLASSIFIED

RTD-TDR-63-9, Vol II

FINAL TECHNICAL REPORT
EVALUATION AND MODIFICATION OF EXISTING PROTOTYPE DYNAMIC CALIBRATION SYSTEM FOR PRESSURE-MEASURING TRANSDUCERS
VOLUME II OPERATING PROCEDURES

TECHNICAL DOCUMENTARY REPORT NO RTD-TDR-63-9, VOL II
March 1963

6593d Test Group (Development)
Air Force Flight Test Center
Edwards Air Force Base, California

Project No 3850 BPSN 3850, Task No 38506

(Prepared under Contract No AF 04(611) 8199
by Houston Engineering Research Corporation
Houston, Texas)

UNCLASSIFIED

TABLE OF CONTENTS

VOLUME I TECHNICAL RESULTS

Section		Page
1	Evaluation of Pressure Transducer Calibration System	1
2	Shock-Tube System	6
3	Mathematical Analysis and Computer Programs	17
4	Data Reduction System	36
Tables		42
Figures		43
References		69

VOLUME II OPERATING PROCEDURES

1	Introduction	1
2	Description	2
	Shock-Tube System	2
	Data Reduction System	3
3	Discussion	4
	Shock-Tube Theory	5
	Shock Tube for Gage Calibration	6
	Data Reduction System	8
4	Procedures	10
	Test Planning	10
	Data Recording	11
	Data Reduction	17
Figures		21
Appendix		27

VOLUME III COMPUTER PROGRAMS

Section		Page
1	Transfer Function Approximation Program	1
	Scope	1
	Preparation of Input Data	2
	Input Data Card Format	4
	Output Data Card Format	7
	Program Operating Procedures	7
	Program Organization	10
2	Input Time Function Approximation Program	13
	Scope	13
	Preparation of Input Data	13
	Input Data Card Format	14
	Program Operating Procedures	14
	Program Organization	17
Appendix		22
	Transfer Function Approximation Program	23
	Input Time Function Approximation Program	29

LIST OF SYMBOLS

SYMBOLS	CONCEPT
a	local sonic velocity, $(\gamma RT)^{1/2}$
d	distance
H	transfer function (frequency domain)
M	Mach number
p	pressure
R	gas constant real part of a complex number
T	temperature upper limit of integration
t	time
U	velocity
γ	ratio of specific heats

SECTION 1 INTRODUCTION

Pressure transducers are devices which measure pressure by converting the deformation of a measuring element to an electrical output. They are classed according to the principle by which they make the conversion from mechanical input to electrical output. The common types are capacitance, strain gage, piezoelectric, and variable inductance. The nature and design of these devices give them high frequency response, thus they may be used for rapidly varying, or dynamic, pressure measurement.

Even though pressure transducers normally have very high natural frequencies, there are some applications where the frequency of the measured pressure is in the same range as the natural frequency. When this occurs, the transducer's output is distorted. Thus it is necessary to calibrate the transducer so its response can be interpreted. This is called dynamic calibration. A common application of pressure transducers where this is necessary is in rocket motor combustion chambers.

This manual describes the equipment used in the Edwards AFB Dynamic Calibration Facility. It explains the dynamic calibration procedure and gives detailed equipment operating instructions.

SECTION 2 DESCRIPTION

SHOCK-TUBE SYSTEM

The shock-tube system includes all of the equipment necessary to excite a test gage, and to record the response of the gage. The shock-tube system may be divided into the shock tube, which is used to excite the test gage, and the data recording system.

SHOCK TUBE A shock tube consists of a tube which is divided into high pressure and low pressure sections separated by a rupture disc, an apparatus for puncturing the rupture disc, and support equipment. The high pressure section is often called the driver section, or compression chamber, and the low pressure section is called the test section, or expansion chamber. Likewise, the rupture disc is often referred to as the burst diaphragm, or just as the diaphragm.

Whenever the rupture disc is punctured, after the driver and test sections have been pressurized, a shock wave is formed which moves down the test section at a speed greater than the acoustic velocity of the gas in the expansion chamber. The shock wave is followed by a constant-pressure region which lasts for several milliseconds at every point along the test section. The purpose of the shock tube in this work is to strike the measuring element of a gage with a pressure step. The blow causes the gage to oscillate or "ring", with a response which depends on the characteristics of the gage. Since the shock wave becomes sharper as it travels, the test-gage ports are placed at the end of the expansion chamber as far as possible from the rupture disc.

A flow diagram of the shock tube and support system is given in Figure 1. The support system includes a high pressure nitrogen (N_2) supply for pressurizing the compression and expansion chambers, and the puncture device. There are provisions for supplying high pressure helium to the compression chamber. This provides a higher pressure-step shock wave than can be obtained with air initially at the same pressure. There is also provision for evacuating the expansion chamber. This allows the use of higher initial pressure ratios (p_3/p_1), which creates higher shock strengths and higher velocities. The N_2 supply is divided so that the lines leading to the compression chamber, expansion chamber and puncture device each have an Apco Model 101 pressure regulating valve, a Helicoid test pressure gage, and a block valve. The block valves are all Grove T series globe valves. The line to the puncture device has a three-way Marotta MV-100 solenoid valve which admits high pressure to operate the puncture mechanism, and then vents the mechanism. The N_2 supplies to the compression and expansion chambers each contain a Marotta MV-100 valve to admit air to their respective chambers, and a solenoid valve to vent their chambers. They also contain Grove T series three-way valves in the air supply lines which serve as manual vents, and Black, Sivals and Bryson 3000 psi burst diaphragms which serve as safety devices.

The driver section has a separate line attached to it which contains a Meletron pressure switch vent and a highly accurate Heise pressure gage with block valve. The expansion chamber has a similar line which contains a Meletron pressure switch, a Heise pressure gage with block valve, a Wallace and Tiernan pressure gage with block valve, and a block valve at a vent.

DATA RECORDING SYSTEM The data recording system is diagrammed, in correct operating arrangement, Figure 2. In this group of equipment there are two blast velocity gages which are used to measure the velocity of the shock wave. These gages are placed in ports on top of the shock tube in the test section. The leads from the blast velocity gages are connected to a Berkeley time interval meter, which measures in microseconds the time interval between the electrical pulse sent out by the two gages on arrival of the shock wave. The electrical pulse from either one or the other of the blast velocity gages is also used to trigger the oscilloscope sweep. The pulse is put into a Schmidt trigger and amplifier, with manual reset. The output from the trigger goes to the input of a Rutherford time delay generator, and the output from it goes to the scope's external sweep input. The output from the test transducer goes to the input of its associated electrical apparatus, which might be a Wheatstone bridge or a cathode follower, depending on the type of transducer. The output of this electrical apparatus goes to the scope's vertical input. A Polaroid camera is used to photograph the test transducers output on the scope screen. Projection type film is used in the camera in this operation.

DATA REDUCTION SYSTEM

The Flying Spot Analog-to-Digital Converter reads the transducer response as recorded on a photographic transparency and converts the film record to digital form. The digital information is recorded on IBM cards and/or printed paper tape. Output data rate is 40 cards per minute when punching cards and a maximum of 300 points per minute otherwise. The seven units comprising the FSADC are (1) the Flying Spot Scanner, (2) the FSADC Digital Unit, (3) Tektronix RM-35 Oscilloscope, (4) Hewlett-Packard 560A Digital Printer, (5) Dymec DY-2512 Card Punch Coupler, (6) FSADC Power Supply and (7) an IBM 523 Card Punch.

SECTION 3 DISCUSSION

Pressure transducers are often used in regions where the rate of pressure change is great enough to cause the transducer to ring. Whenever the transducer output may include the effect of the dynamic characteristics of the transducer, dynamic calibration is required.

Dynamic calibration consists of applying a known high frequency input to the transducer under consideration, recording and evaluating the output. Then it is possible to obtain the transducer's transfer function, which is

$$H = \frac{\text{output}}{\text{input}} \tag{1}$$

For a linear transducer this transfer function is a fixed characteristic, and once it is determined, any input to the transducer may be computed from the output and H.

If it were possible to generate a high-frequency, high amplitude pressure sine wave, the transducer characteristics could be found in the same way the response of a hi-fidelity amplifier is found. Unfortunately there is no known way to generate these high pressure sine waves, so some other function with high-frequency components (such as a step function) must be used. Since it is possible to produce a step function which lasts for several milliseconds in a well designed shock tube, the shock tube is used for dynamic calibration. The size of the step can be easily varied by regulating the initial pressures in the compression and expansion chambers, and can be precisely determined by measuring the velocity of the shock wave.

Whenever a transducer is to be dynamically calibrated the first step is to determine whether or not the response is linear. This can often be done with static calibration, although in some cases the electrical output of the gage decays at such a rapid rate that this cannot be done with sufficient accuracy. If the gage is non-linear in the desired operating range, dynamic calibration with the procedure described here is of no value. At the present there is no practical method for calibrating non-linear pressure transducers. When it is impossible or inconvenient to statically calibrate, the dynamic calibration can be used to establish linearity.

The transducer may act as an accelerometer at the same time it is acting as a pressure gage. When this happens, the output includes response to both pressure and acceleration. The result is that the two effects cannot be separated. A gage which has a significant output when subjected to the acceleration in the test position, should be rejected. If vibration sensitivity limitations in the transducer application are more severe than in the shock tube, vibration sensitivity should be determined prior to dynamic calibration.

The steps in dynamic calibration are:

(1) Obtain Data Record This involves scheduling and performing shock-tube tests on the gage under consideration. The data record is a photographic transparency of the test gage's response as shown on an oscilloscope screen.

(2) Convert Data The transparency of the response is an analog record. In order to handle the data in the mathematical analysis, it is necessary to convert the analog record to a digital form. This is done with the FSADC. The digital record is punched on IBM cards.

(3) Mathematical Analysis The mathematical analysis has been programmed for an electronic computer. The digital data on IBM cards is the input to the computer program. The output is the transfer function of the transducer system.

SHOCK TUBE THEORY

In shock tube operation the gas in the compression chamber is initially at a higher pressure than the gas in the expansion chamber. When the diaphragm separating these two chambers is ruptured, the high pressure gas expands into the low pressure section, generating a shock wave which travels faster than the expanding gas. The action of the gases in the shock tube after the diaphragm burst is shown in Figure 3. The contact surface, which is the boundary between the two initial gases, moves into the low pressure section. The pressure and velocity of the medium on either side of it are the same, though the temperature and density differ. A rarefaction wave moves into the compression chamber, the leading edge of which moves at the velocity of sound in the undisturbed medium. The rarefaction wave is reflected when it reaches the end of the compression chamber and then moves in the opposite direction. It is now moving in the same direction as the shock wave at a higher velocity than the shock wave. If the tube were long enough the rarefaction would overtake the shock wave and cancel it out. Normally, however, the shock tube is designed so that the shock wave reaches the end of the expansion chamber before the rarefaction overtakes it. When the shock wave reaches the end of the expansion chamber it is reflected, and the reflected wave has an amplitude over twice as great as the initial wave.

The relationship between the shock strength, p_2/p_1, and the initial pressure ratio, p_3/p_1, can be described in a mathematical relationship. When the gas in both chambers is N_2, this relationship is

$$\frac{p_3}{p_1} = \frac{p_2/p_1}{\left\{1 - \left(\frac{p_2}{p_1} - 1\right)\left[49 + 42\left(\frac{p_2}{p_1} - 1\right)\right]^{-1/2}\right\}^{7}} \tag{2}$$

This relationship is shown in Figure 4, along with the similar equation for the case with helium in the compression chamber and air in the expansion chamber. Because of the assumptions made in the derivation of equation (2) it is not highly accurate, especially at larger shock strengths.

The relationship between shock strength and Mach Number is given in equation (3).

$$\frac{p_2}{p_1} = 1 + \frac{2\gamma}{\gamma + 1} (M^2 - 1) \tag{3}$$

Whenever N_2 is used in the expansion chamber, regardless of what gas is in the compression chamber, this becomes

$$\frac{p_2}{p_1} = 1 + \frac{7}{6} (M^2 - 1) \tag{4}$$

For the same conditions, the amplitude of the reflected shock wave is

$$p_5 = p_1 \left\{ 1 + \frac{7}{3} (M^2 - 1) \left[\frac{2 + 4M^2}{5 + M^2} \right] \right\} \tag{5}$$

Equations (4) and (5) are highly accurate, and are used for determining test pressures.

SHOCK-TUBE FOR GAGE CALIBRATION

When calibrating pressure transducers with a shock tube, the pressure step can be applied to the gage at some point along the expansion chamber, or at the end of the expansion chamber. The best choice is the end location. This location must be used when the data is used as input to the computer program given elsewhere in this work.

The pressure applied to the gage when it is in the end plate location can be calculated with equation (5). In order to calculate the pressure with equations (4) or (5), it is necessary to know the Mach Number accurately. The Mach Number is defined as

$$M = \frac{U}{a} \tag{6}$$

The velocity is determined by placing two blast velocity gages a known distance apart along the shock tube. They should be placed as close to the point where pressure is to be calculated as possible, because the velocity decreases as the front moves down the shock tube. When a test is made, the time between the arrival of the shock wave at each of the blast velocity gages is measured with a time interval meter. The velocity can then be calculated

$$U = \frac{d}{\Delta t} \tag{7}$$

The speed of sound in the medium inside the expansion chamber can be calculated by the perfect gas law relationship

$$a = \sqrt{\gamma RT} \tag{8}$$

For N_2 this becomes

$$a = \sqrt{2485.72\ T} \tag{9}$$

It is desirable to measure the temperature near the point where the pressure is being calculated, because there is often some temperature difference along a shock tube. The computer program calculates pressure in psi at the end plate whenever temperature in ^{o}F and time interval in microseconds are included in the input data.

It is necessary to know approximately what pressure will be applied to a gage when a given set of pressures are chosen for the compression and expansion chambers. This is to prevent overloading the gage, and to permit testing the gage over the various portions of its range. Predicting the pressure at the end plate with theoretical relationships is not accurate because of losses which occur in the diaphragm burst, and as the shock wave traverses the length of the expansion chamber. A calibration curve giving the reflected, or test, pressure versus the initial expansion chamber pressure with the compression chamber pressure a parameter is given in Figure 5. This curve is valid only for the Edwards AFB transducer calibration shock tube. This curve, then, assists in planning shock tube calibration tests. It gives the range of test pressures which may be obtained with the Edwards AFB shock tube, as well as giving the possible combinations of compression and expansion chamber pressures which result in the desired test pressure.

If high shock strengths are used, the region behind the reflected shock wave will not be at a constant pressure, but will, instead, exhibit a gradually rising pressure. This is not desirable in transducer calibration tests because the mathematical analysis used in transducer evaluation assumes a step input, and

because it casts some doubt on the pressure amplitude calculation. Experiments have shown that initial pressure ratios, p_3/p_1, less than 20 give reflected pressure steps which do not exhibit this phenomenon.

When a pressure transducer is received for dynamic calibration, it may or may not be known that the gage is linear. If it is known to be linear, only one data point would be required to complete calibration of the gage. This point could be anywhere in the gage's pressure range, though a fairly sizable pressure would probably be best. It is recommended that two points be used, and the evaluation obtained with each point be compared. These results should be very similar. Also the amplitude calibration obtained should be compared with the static calibration which indicated that the gage was linear. Whenever the gage's linearity has not been evaluated, or it is impossible to establish it with static calibration, several points over the gage's range, or the range of interest, should be used. Thus the gage's linearity as well as its calibration is obtained.

DATA REDUCTION SYSTEM

Three basic functions of the Flying Spot Analog-to-Digital Converter are (1) scanning the transparency, (2) data conversion, and (3) data output. The end result of these operations is the conversion of an analog record (the transparency) to a digital record suitable for use by digital computers and data processing equipment.

SCANNING THE TRANSPARENCY A lens system housed in the first section of the Flying Spot Scanner focuses the spot of light present on the CRT of the Tektronix RM-35 Oscilloscope onto the transparency housed in a slide holder in the second section of the scanner. The light beam is then focused on the photomultiplier tube mounted in the end of the Flying Spot Scanner. The output of the photomultiplier gain is adjusted so that the spot is detected when it moves through the trace on the transparency.

DATA CONVERSION The FSADC Digital Unit operates from a 60 cps clock. When the digitizing operation is begun by pressing the "Start" button, a submultiple of the 60 cps clock drives a three decade digital counter, called the "X Counter". Following a seven millisecond delay initiated by the input to the X counter, a second counter is enabled. This is a four decade digital counter, called the "Y Counter". It is driven from a 100KC clock. The counting interval of the Y counter ends when the photomultiplier output disables this counter. Coincident with the enabling of the Y counter, the oscilloscope begins a vertical sweep. The sweep rate is 5 milliseconds per centimeter. This is an equivalent counting rate of 500 counts per cm. of the Y counter. Thus the Y counter provides a digital record of the amplitude of the waveform on the transparency at each given X coordinate. The FSADC Digital Unit therefore provides the timing and control functions required to produce a digital record (in the Cartesian coordinate system) of the analog recording provided by the transparency.

DATA OUTPUT The digital data can be recorded on printed paper tape and/or IBM cards. The Hewlett-Packard 560A Digital Printer can be used to record at either the fast or slow digitizing rate. The IBM 523 Card Punch will record only at the slow digitizing rate. A Dymec DY-2512 Card Punch Coupler is utilized to provide the data to the card punch in the serial time form required by the machine. It also permits the manual insertion of eight bits of identification information. The printer operates by positioning print wheels in accordance with the digital data presented to it. An analog output from the printer is used to supply the oscilloscope a voltage to control the horizontal position of the beam, thus making it proportional to the contents of the X counter. Other analog outputs from the printer provide analog voltages corresponding to the X and Y count to permit monitoring the operation. Radical fluctuations of the monitor voltages occur when the print wheels are changed at each print cycle. To prevent these fluctuations from interfering with the monitoring operation a blanking pulse may be obtained from the "+ Gate Out" signal of the RM-35. This pulse can be used to modulate the z axis of the monitor oscilloscope.

SECTION 4 PROCEDURES

In this section detailed procedures are given for planning the calibration tests, for recording the data, and for reducing the data to digital form.

TEST PLANNING

1 Read manufacturer's literature on the gage to be calibrated. Pay special attention to recommended operating procedures.

2 Find the operating pressure range of the gage under consideration, along with the allowable pressure overload.

3 Find out the range over which the gage is to be calibrated.

4 Determine the number of steps, and the magnitude of each, to be applied to the gage.

(a) If the gage is to be calibrated over a narrow range (up to 200 psi) pressures equal to the low end (or as small a step as possible if this is 0), the mid-point, and the high end of the pressure range should be used.

(b) If the gage is to be tested over a wider range (up to 500 psi), use four equally spaced pressures.

(c) The maximum pressure which can be obtained with the Edwards AFB dynamic Calibration shock tube is 1500 psig. If a gage has a range beyond that it cannot be calibrated in the higher part of its range at this facility. To calibrate such a gage use five equally spaced steps starting with the smallest possible and ending with 1500 psig. Note that the smallest step depends on the selection of gases and burst diaphragm available. For example, using a 50 psi burst diaphragm and air-to-air operation the smallest pressure step obtainable is 25 psi.

5 Determine the initial pressures required in the driver and test sections to obtain the desired pressure steps.

(a) For air-to-air operation initial pressures can be determined with the calibration curve on Figure 5.

(b) For the desired test pressure (reflected shock wave pressure, p_5) pick a valve for the driver chamber (p_3) from the operating envelope. Record the test section pressure (p_1) corresponding to these two pressures.

6 In order to avoid overpressuring the test gage, make a low pressure-step test and record the first millisecond of the transducer's response. Estimate the

ratio of the peak of the highest swing of the trace to the steady-state value of the trace. (The steady-state value corresponds to the input pressure-step, $p_5 - p_1$.) Then, for the highest pressure test planned in Item 5, multiply this ratio times $(p_5 - p_1)$ and add it to p_1. If the resulting pressure exceeds the maximum allowable pressure of the gage (including overload) reduce the test pressure by the difference between the two.

7 Perform the tests planned in Item 5.

8 Place a blind flange between the shock tube and the flange holding the test gage (use a spacer to prevent the gage from bearing against the blind flange). Then repeat one of the tests performed in Item 7. This provides a record of the gage's vibration sensitivity.

DATA RECORDING

1 Turn on power to all electronic equipment (remember warm-up periods are up to 60 minutes).

The power line for the electronic counter should remain connected at all times in order to keep crystal oven in operation. The power switch on front panel may be turned off while the oven remains on.

2 Set up equipment as shown in Figure 2.

3 Triggering System (synchronization)

(a) Set Trigger Slope on Trigger Unit to +

(b) Set Delay Generator controls as follows

Delay . . . . internal (int)

Trigger Switch . . . . negative (neg)

$\left.\begin{array}{l}\text{Delay Range}\\ \text{Delay Dial}\end{array}\right\}$ . . . . desired delay

4 Velocity Measurement System

Set electronic counter controls as follows

(a) Function Selector . . . . TIME INTERVAL

(b) Display Time . . . . desired display time

(c) Connect start signal to START INPUT connector and stop signal to STOP INPUT connector. (Figure 2).

(d) Set COM-SEP switch to SEP. Note: If start and stop signals come from common source, set COM-SEP switch to COM and connect signal to either input connector.

(e) Set START TRIGGER SLOPE switch to positive to start measurement on positive-going portion of signal; set to negative to start measurement on negative-going portion of signal.

(g) Set START TRIGGER LEVEL controls to start measurement at desired voltage level (DC, 1 volt for Atlantic Research Blast Velocity Gage). Select ac or dc coupling when setting MULTIPLIER.

(h) Set STOP TRIGGER SLOPE switch to positive to stop measurement on positive-going portion of signal; set to negative to stop measurement on negative-going portion of signal.

(i) Set STOP TRIGGER LEVEL controls to stop measurement at desired voltage level. Select ac or dc coupling when setting MULTIPLIER.

NOTE: See Paragraph 2-6 in Counter Instruction Manual for using oscilloscope to help set TRIGGER LEVEL controls.

(j) Read time interval in units selected by TIME UNIT switch.

5 Scope settings for transient operation (Hughes Memo-scope)

Intensity	12:00 o'clock
Focus	desired line width
Astigmatism	
Vertical Position	desired level
Volts/division	desired level
Input	A-DC
Time/division	desired setting
Magnifier	IX
Sync Slope	- (negative)
Sync Mode.	EXT (external)
Multiplier	desired setting

Variable . . . . CAL (calibrate)

Sync Level . . . . 12:00 o'clock

Stability . . . . Turn left till light goes out and reset
light remains on when sweep switch is depressed

Sweep . . . . SINGLE

Horizontal position . . . . . . desired

Storage . . . . NORM

Threshold . . . . 1:00 o'clock

Calibrator . . . . OFF

6 Scope settings for free running operation (Hughes Memo-scope)

Same as Item 5 except

Sync Slope . . . . + (positive)

Sync Mode . . . . INT (internal)

Stability . . . . Counter-clockwise position

Sweep . . . . NORM

7 Scope settings for transient operation (Tektronix RM-35) with Type D Plug-In Unit

(Get free running trace on screen)

Vertical Position . . . . desired position

Focus . . . .

desired line width

Astigmatism . . . .

Intensity . . . . 2:00 o'clock

Input . . . . A-DC

Volts/division . . . . desired level

Delaying Sweep Section . . . not used

Calibrator . . . . OFF

Horizontal position . . . . . . desired position

Time/division. . . . . desired setting

Trigger Level . . . . 1:00 o'clock

Stability . . . . adjust sweep stability until trace just extinguishes.

Triggering Mode . . . . AC-SLOW

Triggering Slope & Mode. . . . . . EXT-NEG

Horizontal Display . . . . Main Sweep Normal

8 Scope settings for free running operation (Tektronix)

Same as Item 7 except

Stability . . . . Counter-clockwise position

Trigger Slope & Mode. . . . . INT-POSITIVE

9 Pressure Measurement (See manufacturers instructions for specific transducer systems. Examples are given in the Appendix).

10 Shock Tube Operation

(a) Turn on power to console and put all solenoid valve switches to "off" position.

(b) Vent entire system

(c) Open the supply valve at the console

(d) Open block valves to admit air to pressure regulating valve

(e) Set driver and test section pressure regulators to desired values. These can be determined from Figure 5, using the desired pressure input to the test gage.

(f) Set the puncture pressure regulator about 250 psi above the driver pressure

(g) Open the block valves on the downstream side of the pressure regulators

(h) Place a diaphragm of the proper burst pressure in the shock tube breech, close and lock the breech. The diaphragm is chosen according to the initial pressure difference between the driver and test sections.

(i) If less than atmospheric pressure is desired in the test section, connect the vacuum pump and evacuate the section to the desired level.

(j) Press the driver section load switch located on the console to the "on" position and hold until the driver section pressure reaches equilibrium at the preset pressure. When applicable, do the same with the test section.

<u>Note</u>: Always pressurize the driver section before the test section to avoid deforming the burst diaphragm.

Example: Suppose it is desired to perform a test with a pressure ratio of four, with the driver section at 800 psia and the test section at 200 psia. A diaphragm which would burst at 650-700 psi would be used. This diaphragm would burst if the driver section were loaded to 800 psia, therefore the proper procedure would be to load the driver to 400-500 psia, then load the test section to 200 psia, and then complete the loading of the driver section to 800 psia.

(k) The shock tube is now ready for operation. It may be operated by pressing the "fire" button on the console.

11 Record required information on the data sheet. A sample data sheet is given in the Appendix.

12 Firing and Photographing Sequence.

With all previous steps accomplished proceed with the following

(a) Verify operation of the scope sweep triggering circuit using test trigger on trigger unit.

(b) Mount polaroid camera on scope

Note: The optimum conditions for photographing depend on factors varying from case to case.

Good pictures were obtained by setting the camera as follows for

BLACK AND WHITE PRINTS: (For intensity set at 2:00 o'clock)

Free Running Trace using Type 47 Polaroid film
lens opening f8
shutter speed 1/5

Transient Trace using Type 47 Polaroid film
lens opening f8
shutter speed T

TRANSPARENCIES: (For intensity set at 2:00 o'clock)

Free Running Trace using Type 46-L Polaroid film
lens opening wide open
shutter speed T

(c) Check reset light on trigger unit

(d) Press the camera cable release to open shutter

(e) Press the fire switch on the console

(f) Press the camera shutter cable to close shutter

(g) Pull the polaroid film through the camera and wait the proper development time.

(h) Push to "on" the driver and/or test section vent switches on the console to depressurize the shock tube.

(i) Wait until the shock tube is depressurized; then open diaphragm clamp and remove the ruptured diaphragm.

13 Transparency Development Instructions

(a) Open the metal cover hinged to the Dippit. (If the lips of the Dippit stay closed because of long storage, simply pry them open.) Hold Dippit at the sides, in an upright position.

(b) Holding the picture by the tab, slide it carefully into the Dippit as far as it will go, leaving at least 3/4" of the tab outside the Dippit. As you insert the picture be careful not to buckle it; the image side must not touch the lips or the inside of the Dippit.

(c) Close the metal cover tightly, pressing it down as far as possible. Be sure the picture tab comes out at least 3/4" through the slot in the metal cover.

(d) Turn the Dippit upside down so that the liquid completely covers the transparency. Hold upside down for at least 20 seconds while agitating briskly. IMPORTANT: The transparencies should be dipped within the first 10 minutes. If you wait longer than this, dipping time must be increased to 45 seconds. The transparency should always be dipped within one hour to prevent eventual discoloration.

(e) Turn the Dippit right side up. With the cover still closed pull the transparency out with a rapid motion. The lips of the Dippit will squeeze excess moisture from the transparency.

14 Transparency Touch-up Process

Hold the transparency up to the light. There will probably be a large number of pin holes observable. These pin holes will cause occasional errors to be recorded by the FSADC, and should be eliminated.

(a) Place a light behind the transparency with the emulsion side away from the light. A light table is excellent for this.

(b) Paint out all observable pin holes with Kodak Opaque using a small brush. If part of the trace is inadvertently painted, the paint can be removed by touching it with a clean brush dipped in water.

15 Transparency Mounting Instructions

(a) The transparency should be allowed to harden for eight hours before mounting.

(b) The mount is composed of two parts, one frame with tabs on it, called Part A, and a frame with holes in it corresponding to the tabs, called Part B.

(c) Tear off tab along perforation of the transparency.

(d) Place the transparency in position within the eight guides on Part A of the mount.

Note: One corner of the transparency has a diagonal corner cut-off. This should be fitted against the diagonal guide of Part A.

(e) Snap each of the notches on Part B so that it locks with the matching guides of Part A.

DATA REDUCTION

GENERAL OPERATING PROCEDURES

1 Remove the camera from the second section of the Flying Spot Scanner.

2 Insert the desired slide into the slide holder.

3 Close the second section and open the first section.

4 Set the lens to time exposure (T) and f 1.9.

5 Close the first section.

6 Remove the Vertical Amplifier Plug-In Unit from the oscilloscope and insert the altered Tektronix Type T Plug-In Unit. Set to 5 milliseconds per cm.

7 Set MAGx5 position on the oscilloscope to the OFF position.

8 Insert the Flying Spot Scanner connector into its receptacle at the lower right of the FSADC Digital Unit beside the OK indicator.

9 Install the cable between the oscilloscope plug-in unit and receptacle adjacent to the POWER switch of the FSADC Digital Unit.

10 Turn on the FSADC Digital Unit, the RM-35 oscilloscope, the printer, and the card punch coupler.

11 When the numeric displays of the X and Y counters are illuminated (approximately one minute after applying power), press the RESET button and hold until the printer has printed.

12 Press the HV button on the FSADC Digital Unit.

13 Set printer to record.

14 Allow a warm-up period of at least two hours before proceeding.

DETAILED OPERATING PROCEDURE

1 After warm-up, set the TOTAL COUNT switch to 100 and press START button. Press the STOP button when the Y counter indicates a count.

2 Observe the photomultiplier output (PM output on Flying Spot Scanner Unit) with another oscilloscope. Adjust the PM GAIN until the negative pulse just crosses zero volts. Press the START button and observe the PM output as the unit continues to scan. Re-adjust PM GAIN if necessary to make sure that the PM output always crosses zero volts regardless of X position. Press STOP button.

3 If it is desired to monitor the digitizing operation, connect the X and Y monitor outputs on the printer to an oscilloscope. Modulate the axis with the + GATE of the altered Type T Plug-In. Adjust the vertical and horizontal gains of the oscilloscope until the desired display is obtained on the CRT. This may require a partial trial run. If a Hughes Memo-scope is available the monitoring can be done directly. Otherwise it will be necessary to photograph the monitor and observe the photograph for proper results.

4 Set MASK/LINE selector to LINE.

5 Set FAST/SLOW switch to SLOW when punching cards, FAST otherwise.

6 Set TOTAL COUNT selector for the number of samples desired.

7 Press RESET button.

8 Set SPACE SELECTOR on the digital printer to 1.

9 Set MODE selector on the card punch coupler to AUTOMATIC if punching cards, to OFF otherwise.

10 Dial in the proper identification data on the coupler in the following order from left to right: (1) the date using the month, day, and last digit of the year, (2) the run number, and (3) the total count number using 1, 2, 5, or 0 for 100, 200, 500 and 1000 respectively. For example, suppose we have the date 7 April 1963; run number 42; and 500 samples. The manual data entry would be 04073425. Care should be exercised to use a zero in the ten's position for any number less than ten but which is allowed two digits.

11 Turn on the IBM 523 Card Punch if it is desired to punch cards. Load the machine with a supply of blank cards and press the START switch on the card punch.

12 Press the RESET button on the FSADC Digital Unit and hold until the zero X position has been recorded by the punch and/or printer. Then press START button. The system will now digitize until the last horizontal count. At this time press the RESET button again which records the 1000 X position (will record as 000).

13 If at any time the digitizing operation stops before completion; check the card punch for an overrun in the card stacker, an exhausted blank card supply, or a mutilated card. When any of these has occurred, the system will continue operation as soon as this is remedied.

14 At the conclusion of a digitizing run if punching cards, press the START button on the IBM 523 and hold until three cards have run through. Remove all cards from the card stacker. They are now ready for editing and the addition of identification information before being processed by the digital computer.

15 At any point of possible error during the operation an asterisk is printed on the tape in the fifth column from the right. On the IBM card, the possible error is noted by <u>not</u> punching row 9 in column 11. If, at a point of possible error, the Y counter output was zero, no spot was detected. If a number other than zero occurs, two spots were detected and the lowest value is recorded.

CALIBRATION Specific instructions for calibration of the FSADC Digital Unit are: (Refer to Figure 6)

<u>Horizontal Zero Adjust</u> The HOR ZERO ADJ potentiometer is located in the RM-35 oscilloscope (also labeled SWP/MAG REGIS R262). Adjust so the vertical line at X count of zero is exactly at the left edge of the oscilloscope template. Figure 6 - 1

<u>Horizontal Span Adjust</u> This potentiometer is located in the digital printer and labeled HOR DEFL SPAN. Adjust so the vertical line at X count of 999 is coincident with the notches on the right edge of the oscilloscope template Figure 6 - 2

Vertical Zero   This is a fine adjustment on the front panel of the altered Type T Plug-In Unit. A coarse adjustment may be found inside, labeled POS RANGE R8570. Adjust so that bottom of the vertical line is coincident with the bottom edge of the oscilloscope template. Figure 6 - 3

Other Adjustments   The remainder of the adjustments required for this unit may be located in the Flying Spot Analog-to-Digital Converter Manual.

The required calibration and adjustment information for (1) the RM-35 Oscilloscope, (2) Hewlett-Packard 560A Printer, (3) Dymec DY-2512 Card Punch Coupler, and (4) the IBM 523 Card Punch may be found in their respective instruction manuals.

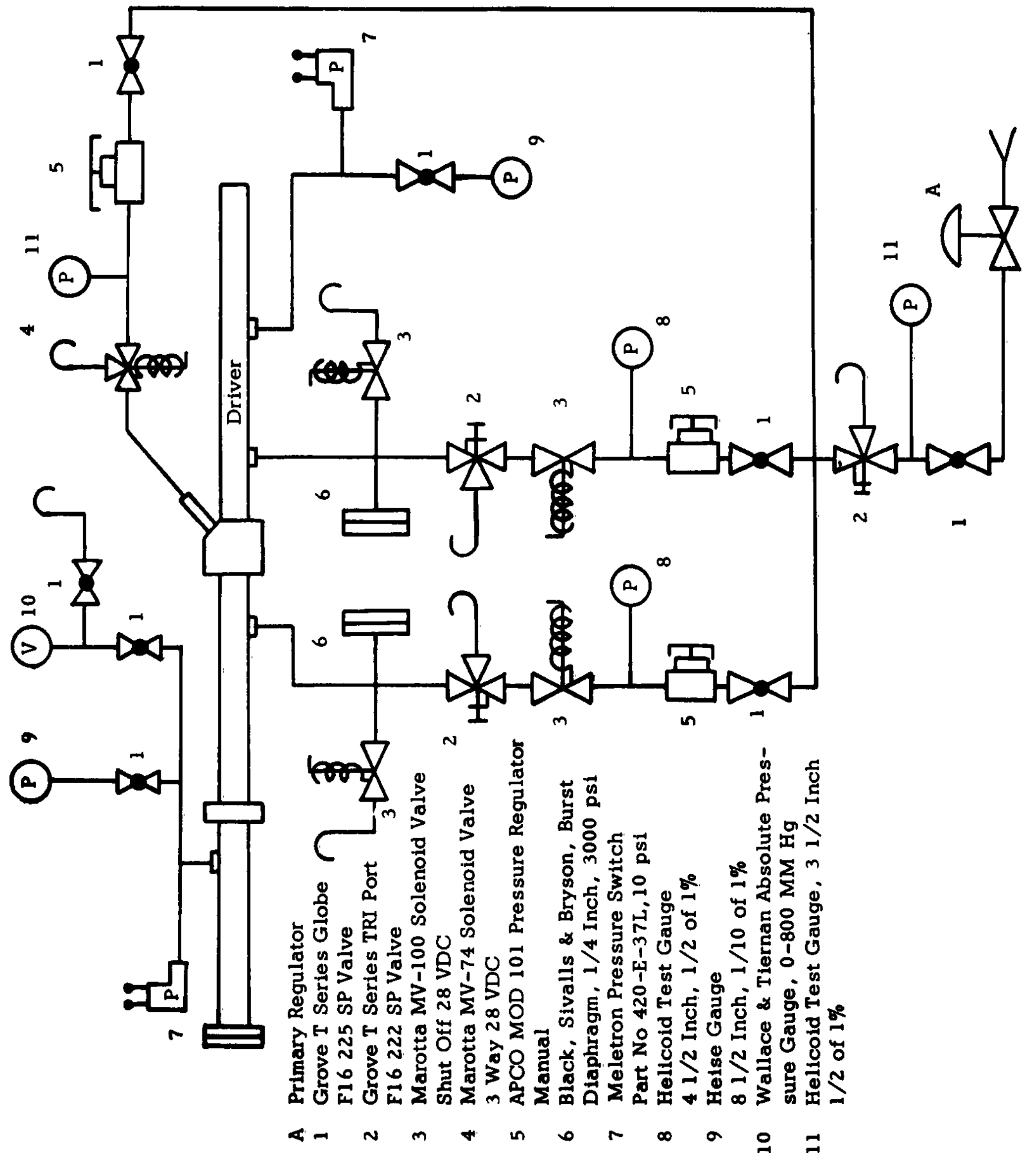


FIGURE 1 SCHEMATIC OF SHOCK TUBE AND PNEMATIC SYSTEM
EDWARDS AFB DYNAMIC CALIBRATION FACILITY

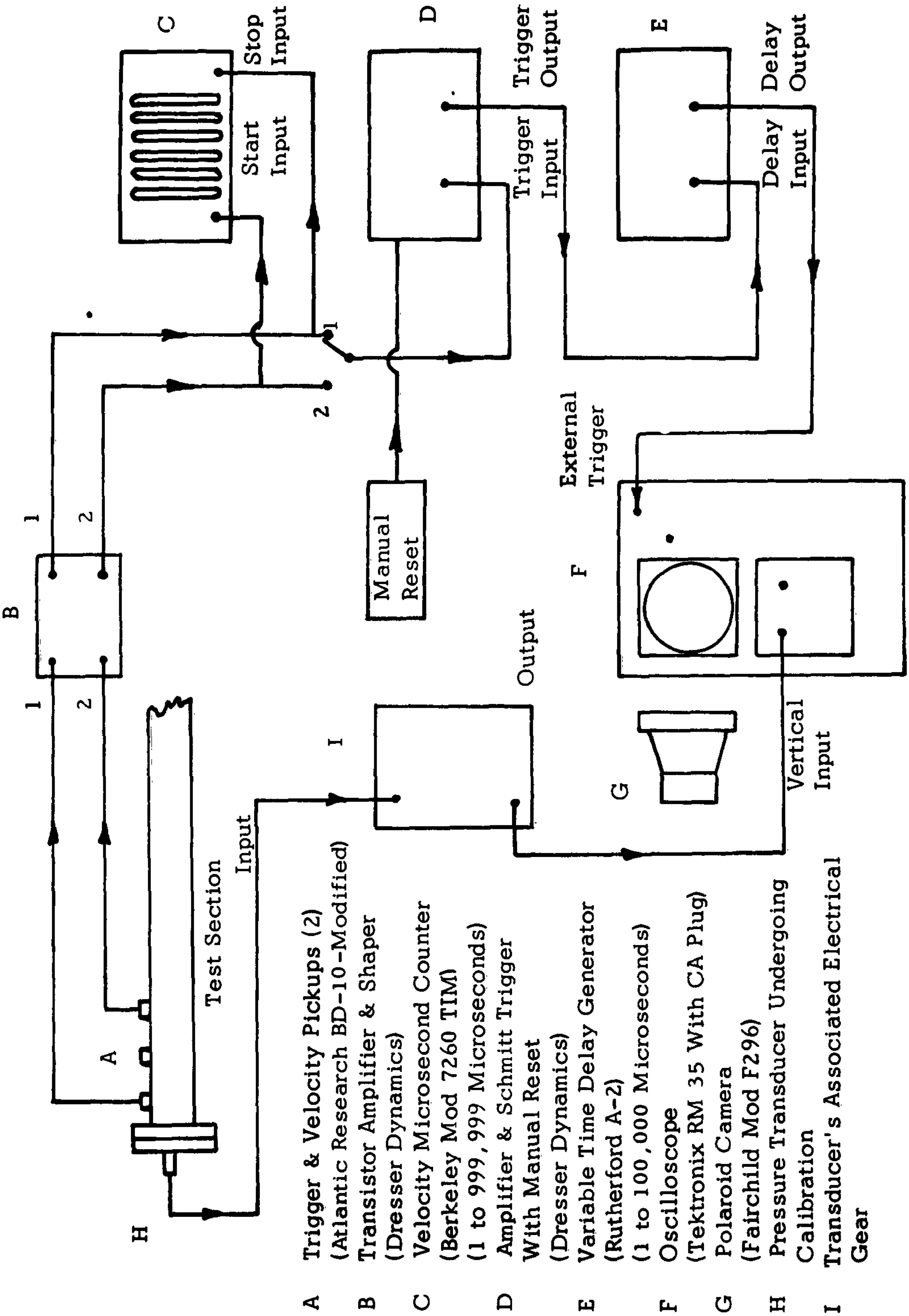


FIGURE 2 SCHEMATIC OF DATA RECORDING SYSTEM EDWARDS AFB DYNAMIC CALIBRATION FACILITY

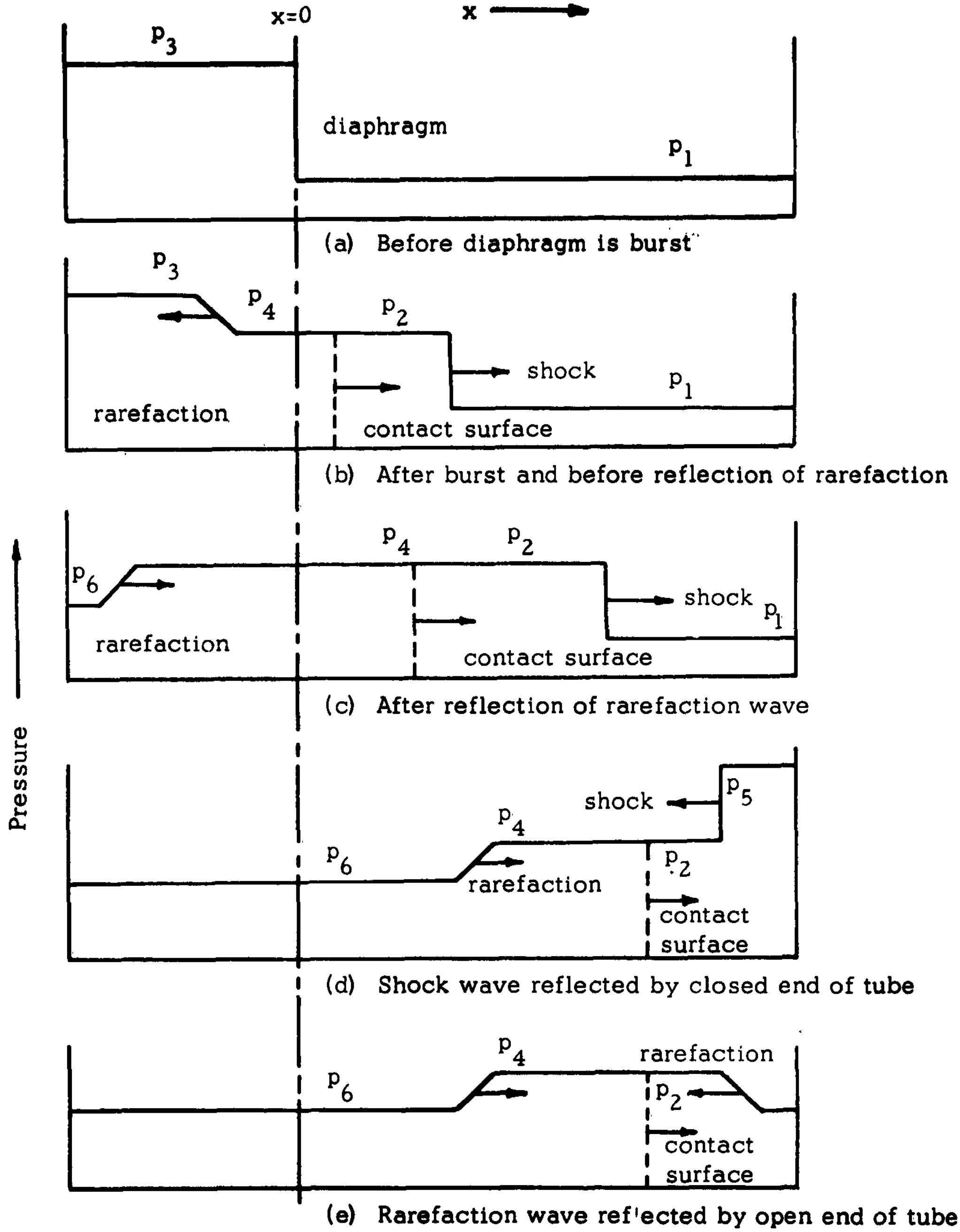


FIGURE 3 PRESSURES AND WAVES IN SHOCK TUBE

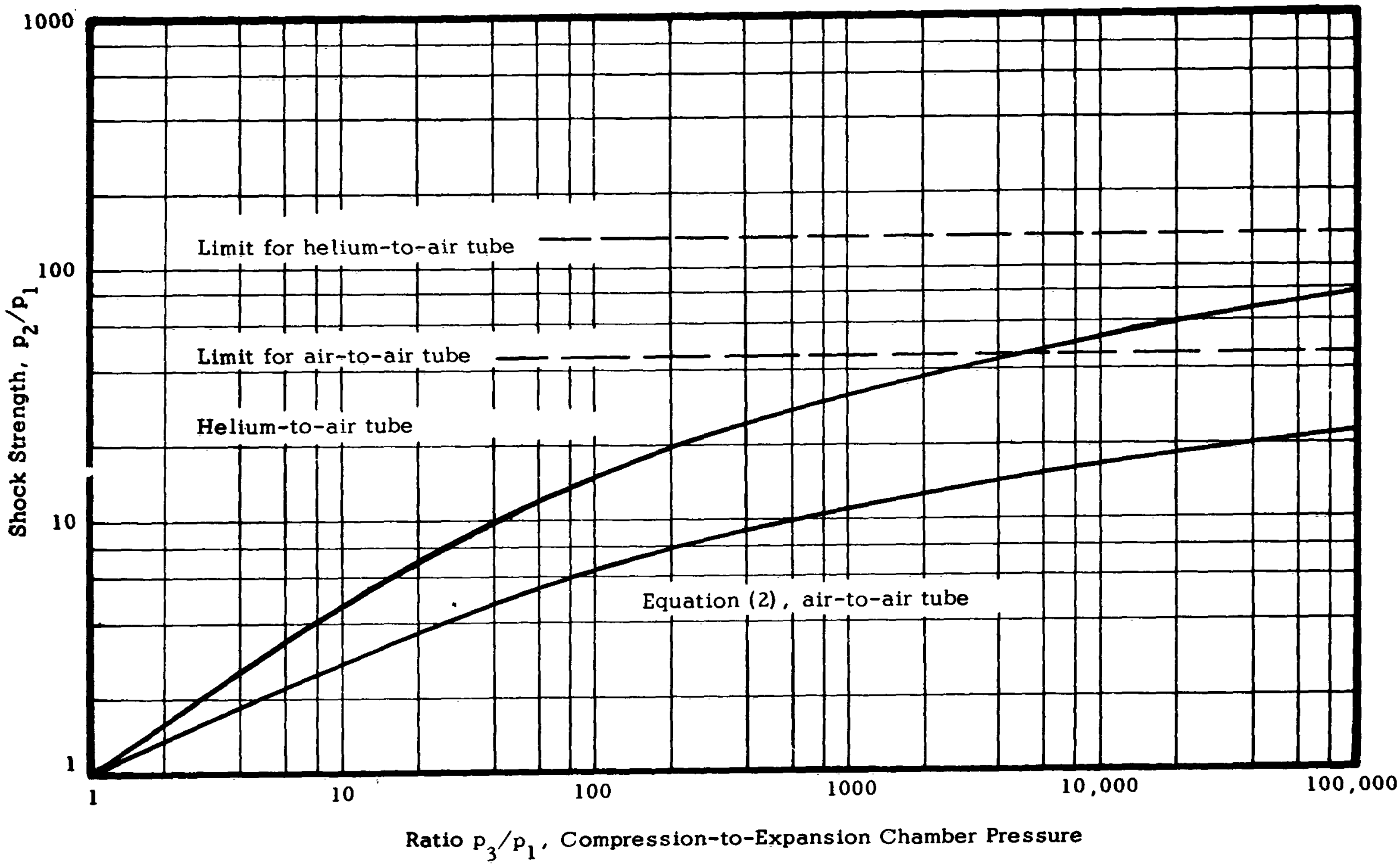


FIGURE 4 RELATION BETWEEN COMPRESSION CHAMBER PRESSURE AND SHOCK STRENGTH

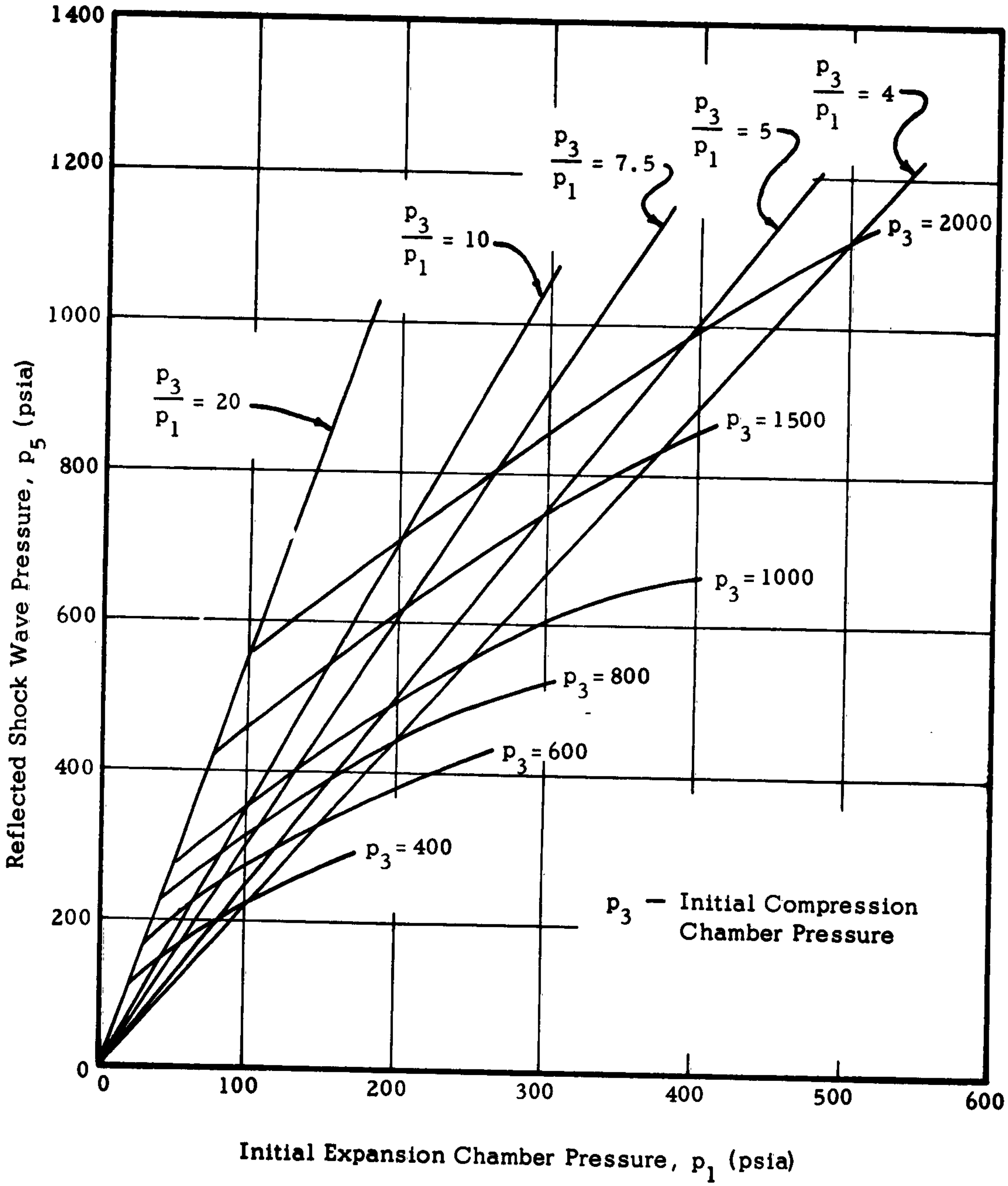


FIGURE 5 SHOCK TUBE CALIBRATION CURVE

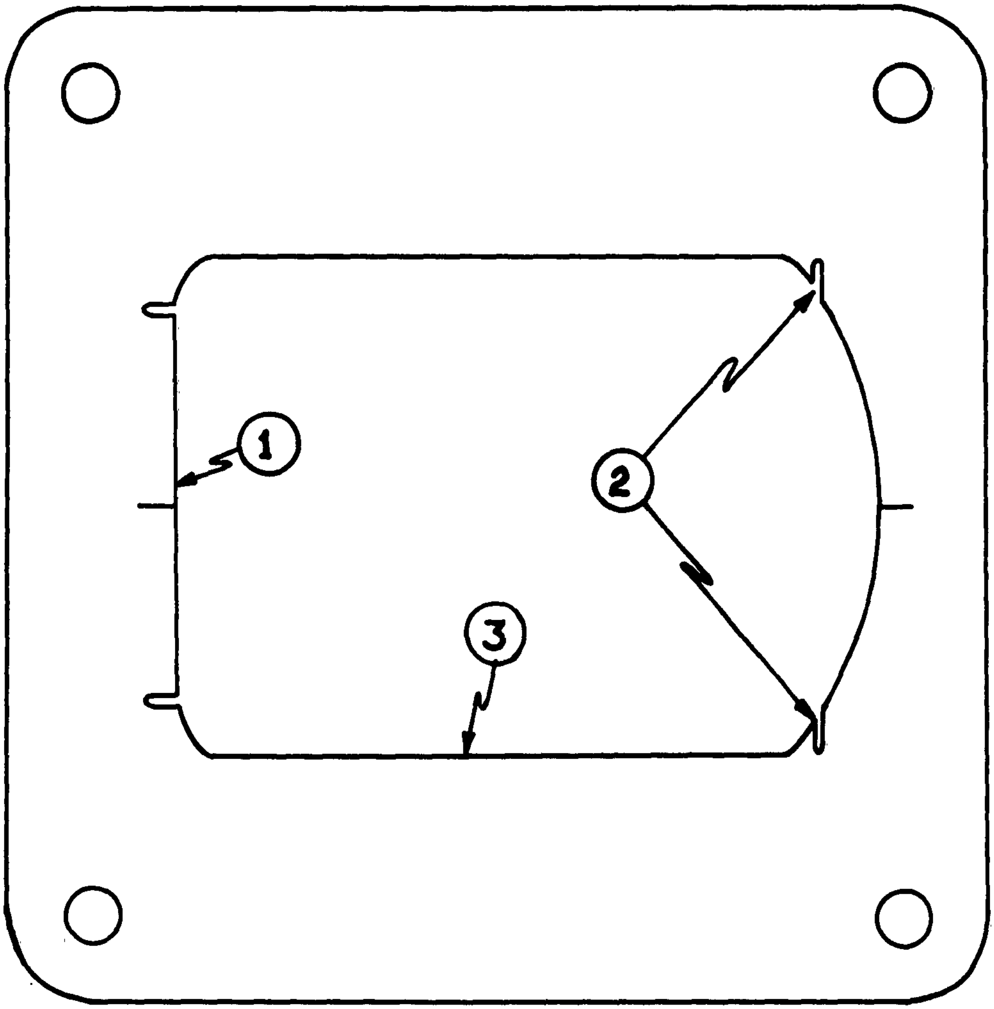


FIGURE 6 OSCILLOSCOPE TEMPLATE

APPENDIX

PRESSURE MEASUREMENT WITH THE ELASTRONICS SYSTEM

ARRANGEMENT OF EQUIPMENT

See Figure 2

CALIBRATION PROCEDURE

1 Turn the Selector Switch on the front panel from "OFF" to "1.5 V TEST BAT", and give the Dyna-Electrometer a warm-up period of more than fifteen (15) minutes.

The 1.5 volt battery for heating the filament of the Electrometer tube has a useful life of 3000 hours. When the Selector Switch is in "TEST BAT" position, the meter pointer should point at approximately 50 microampere incicating that there is no deterioration of the battery (when the battery voltage is low, pull out the unit from its casing and replace the 1.5 volt battery).

Press the "DISCHARGE" switch momentarily to discharge any residual charge.

2 If the meter is not indicating "ZERO" following the discharging process, adjust the black knob (marked ZERO) until the pointer indicates Zero. After this, if the pointer drifts continuously, then adjust the smaller red knob (marked "DRIFT ADJ.") by turning it in the opposite direction to that of pointer drift until zero or minimum drift is obtained. When properly done this insures virtually drift free operation.

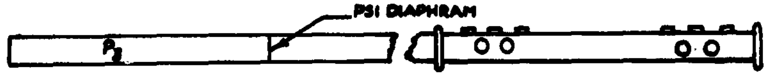
3 This Electrometer has a negative-going signal; therefore scope controls should be adjusted to compensate for it.

4 Put shock tube into operation as described in operating instructions.

TRANSDUCER EVALUATION RUN RECORD

1 → 72

010 CARD 1	
010 CARD 2	
010 CARD 3	



DRIVER PRESSURE , P_3 = ____ PSI

STTD 1 (4TH CARD)

EXPANSION CHAMBER PRESSURE , P_1 (1 → 8) PSI	AMBIENT PRESSURE , P_A (9 → 16) PSIA
TEMPERATURE (17 → 24) °F	DISTANCE BETWEEN BLAST GAGES (25 → 32) FT
TIME INTERVAL (33 → 40) MICRO-SEC	RATIO OF SPECIFIC HEATS , γ (41 → 48) UNITLESS
SPECIFIC GAS CONSTANT, R (49 → 56) $\frac{FT \cdot LB}{LB\ °F}$	SCOPE VERTICAL SENSITIVITY (57 → 64) MV/CM
SCOPE HORIZONTAL SWEEP (65 → 72) MICRO-SEC/CM	73 → 80

PHOTOGRAPHS / REMARKS

DD 1 (5TH CARD)

NO. INPUT DATA POINTS (7 → 10)	FINAL VALUE OF TRANSIENT (11 → 20)
BEGINNING FREQUENCY (21 → 30)	FINAL FREQUENCY (31 → 40)
FREQUENCY INCREMENT (41 → 50)	51 → 60

SIGNATURES

PROJECT ENGINEER	
TEST CONDUCTOR	
OBSERVER	OBSERVER

Research & Technology Division, Edwards AF Base, Calif. Rpt. No. RTD-TDR-63-9. EVALUATION AND MODIFICATION OF EXISTING PROTOTYPE DYNAMIC CALIBRATION SYSTEMS FOR PRESSURE-MEASURING TRANSDUCERS (U). Final Report, Vol II, 29 p incl illus.

Unclassified Report

This report describes the equipment used at the EAFB pressure transducer Dynamic Calibration Facility and gives detailed equip- ment operation instructions.

1 Instrumentation
I Project 3850
Task 38506
II Contract No
AF 04(611)-8199
III Houston
Engineering
Research
Corporation
IV J L Schweppe
J L Williams
A H McMorris
W R Busby
V In ASTIA
collection

Research & Technology Division, Edwards AF Base, Calif. Rpt. No. RTD-TDR-63-9. EVALUATION AND MODIFICATION OF EXISTING PROTOTYPE DYNAMIC CALIBRATION SYSTEMS FOR PRESSURE-MEASURING TRANSDUCERS (U). Final Report, Vol II, 29 p incl illus.

Unclassified Report

This report describes the equipment used at the EAFB pressure transducer Dynamic Calibration Facility and gives detailed equip- ment operation instructions.

1 Instrumentation
I Project 3850
Task 38506
II Contract No
AF 04(611)-8199
III Houston
Engineering
Research
Corporation
IV J L Schweppe
J L Williams
A H McMorris
W R Busby
V In ASTIA
collection

Research & Technology Division, Edwards AF Base, Calif. Rpt. No. RTD-TDR-63-9. EVALUATION AND MODIFICATION OF EXISTING PROTOTYPE DYNAMIC CALIBRATION SYSTEMS FOR PRESSURE-MEASURING TRANSDUCERS (U). Final Report, Vol II, 29 p incl illus.

Unclassified Report

This report describes the equipment used at the EAFB pressure transducer Dynamic Calibration Facility and gives detailed equip- ment operation instructions.

1 Instrumentation
I Project 3850
Task 38506
II Contract No
AF 04(611)-8199
III Houston
Engineering
Research
Corporation
IV J L Schweppe
J L Williams
A H McMorris
W R Busby
V In ASTIA
collection

Research & Technology Division, Edwards AF Base, Calif. Rpt. No. RTD-TDR-63-9. EVALUATION AND MODIFICATION OF EXISTING PROTOTYPE DYNAMIC CALIBRATION SYSTEMS FOR PRESSURE-MEASURING TRANSDUCERS (U). Final Report, Vol II, 29 p incl illus.

Unclassified Report

This report describes the equipment used at the EAFB pressure transducer Dynamic Calibration Facility and gives detailed equip- ment operation instructions.

1 Instrumentation
I Project 3850
Task 38506
II Contract No
AF 04(611)-8199
III Houston
Engineering
Research
Corporation
IV J L Schweppe
J L Williams
A H McMorris
W R Busby
V In ASTIA
collection